

# Facilitating Conflict Resolution of Models for Automated Enterprise Architecture Documentation

*Completed Research Paper*

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## ABSTRACT

Enterprise Architecture (EA) management relies on solid and up-to-date information about the current state of an EA. In current practices the manual collection of information is prevailing resulting in an error-prone, time-consuming, and expensive task. Recent research efforts seek to automate this task by integrating existing information sources in the organization to optimize the EA documentation process. While automation of EA documentation enables many advantages, the transformation of the collected information to an EA model remains an unresolved challenge since it cannot be automated completely. In particular, conflicts resulting from partial transformations require involvement of EA Stakeholders possibly not having a technical background. In this paper we propose an approach for the conflict resolution facilitating our long-term goal of automated EA documentation. We illustrate our approach using a productive Enterprise Service Bus from a leading organization of the fashion industry and evaluate our approach with expert interviews.

## Keywords

Enterprise Architecture, automated EA documentation, model transformation, conflict resolution

## INTRODUCTION AND MOTIVATION

Rapidly changing market requirements, globalization, and increasing complexity compel organizations to adapt their information technology (IT) management practices. Enterprise Architecture (EA) is promoted as means to overcome these challenges and achieve a better alignment of strategy, business, IT, and personnel using a holistic model of the organization (Kaisler, Armour, and Valivullah 2005; Weill and Ross 2009; Espinosa, Armour, and Boh 2011). This model covers information on infrastructure components, business applications, business processes, and relationships among them. A recent survey on EA documentation reveals a large amount of manual work for the collection of the required information for this model (Roth, Hauder, Farwick, Matthes, and Breu 2013). This high degree of manual work combined with the increasing volume of EA information of organizations leads to very error-prone, time-consuming, and expensive maintenance of EA models (Roth et al. 2013). EA documentation needs to achieve and sustain a high quality in the collected information to provide decision makers with proper information (Grunow, Matthes, and Roth 2012). For this purpose, automated EA documentation has been proposed as a promising approach to tackle these challenges.

In our recent work, (Buschle, Ekstedt, Grunow, Hauder, Matthes, and Roth 2012) we evaluate an Enterprise Service Bus (ESB) as information source for automated EA documentation. We describe the coverage of an EA model by automatically

gathering and transforming information from a productive ESB. In (Buschle et al. 2012) we manage to retrieve EA information relevant to the infrastructure and application layers of ArchiMate (The Open Group 2012). Based on our empirical study (Roth et al. 2013) we diagnose that EA documentation is a major challenge for EA initiatives and adequate tool support is essential. We also observed that automation techniques reduce efforts for EA documentation in practice.

Since the automated gathering and maintenance of EA models depends on appropriate information sources, we empirically evaluated existing systems for EA documentation that can be utilized in organizations in (Farwick, Hauder, Roth, Matthes, and Breu 2013). Next to the relevance of the information in these systems for EA, we evaluated data quality attributes for information sources, i.e., actuality, completeness, correctness, and granularity. Further, we revealed on which particular layers in an EA model this information is located.

Major challenges towards automated EA documentation are concerned with the transformation to align the collected information with the target EA model. These challenges require additional steps performed by EA Stakeholders in a semi-automated manner (Hauder, Matthes, and Roth 2012). This includes abstraction gaps between an EA model and imported information from operative systems, since this information is often too fine-grained for mere EA purposes. Another challenge is duplicated EA elements that can be imported from different information sources, so that they have to be removed in an additional quality assurance step. The imported concepts can also be ambiguous requiring data cleansing mechanisms. These transformation challenges demand technical solutions that raise abstraction level of the imported information and incorporate EA Stakeholders in the resolution of conflicts that cannot be resolved automatically. In this paper, we propose a solution to incorporate EA Stakeholders and Data Owners to facilitate the resolution of conflicts and provide a mechanism to perform the quality assurance of the imported data in the EA repository.

## STATE OF THE ART IN ENTERPRISE ARCHITECTURE DOCUMENTATION

A federated approach for EA model maintenance is proposed in (Fischer, Aier, and Winter 2007) by integrating existing models from specialized architectures. Processes and roles for EA model maintenance are proposed and evaluated at a large financial service provider. However, this approach does not detail on how the loading of the specialized architectures can be automated. Although the presented process contains several quality assurance activities, the paper does not describe how these steps are performed in detail. In (Farwick, Agreiter, Breu, Ryll, Voges, and Hanschke 2011), a process for automated EA model maintenance is presented. In contrast to Fischer et al., Farwick et al. gather data from technical interfaces automatically. The process also includes human tasks for the resolution of conflicts that appear within the collection process. However, the activities and details for the conflict resolution are not detailed in this paper and the essential involvement of EA Stakeholders in this step remains unresolved.

Automating EA documentation using models of an ESB is presented in (Buschle et al. 2012). The authors present a reverse engineered meta-model of SAP PI and model transformations for three EA models are illustrated. The model coverage for these three models is ascertained with the majority of the gathered EA information relevant for the infrastructure and application layer. The paper does not detail how conflicts after the model transformation can be resolved or how human tasks for the quality assurance can be invoked. In (Buschle, Holm, Sommestad, Ekstedt, and Shahzad 2011) an approach to automatically create EA models is presented. They use a vulnerability scanner that provides information regarding the network architecture, whereas the scanner also identifies operating systems and services. Similar to the aforementioned approaches, the paper does not describe how conflicts during data collection and maintenance can be resolved.

In (Roth et al. 2013) an empirical study on current practices and future directions on EA documentation is conducted. The paper evaluates four research hypotheses on EA documentation in organizations. One of the key challenges EA initiatives in organizations are faced with is the documentation of their EA. This includes the data quality of the EA model as well as the time consuming task of collecting this information. The efficiency and effectiveness of the documentation also depend on the team organization and adequate tool support. The paper reveals that organizations already applying automation techniques were able to decrease the effort of EA documentation. Another empirical study on automated EA documentation was conducted in (Farwick et al. 2013). The authors investigate information sources for automated EA documentation in organizations and detail these by different data quality attributes and contained EA information. Although, both papers provide no solutions for automated EA documentation, they can be regarded as empirical foundation for the research conducted in this paper.

Challenges for automated EA documentation based on a literature review, a survey, and a practical example are shown in (Hauder et al. 2012a). The identified challenges are summarized as taxonomy with four categories, i.e. data, transformation, business and organizational, and tooling. Hauder et al. briefly discuss a solution for challenges of the transformation category. Requirements for automated EA model maintenance divided into the categories architectural, organizational, integration or data source, data quality, and functional as well as non-functional are presented in (Farwick et al. 2011b).

Farwick et al. mainly contribute to the integration of data source and data quality requirements. An EA documentation process that explicitly includes information sources is proposed in (Moser, Junginger, Brückmann, and Schöne 2009). However, the process description only mentions a need to evaluate changes by EA Stakeholders, without describing how this step can be performed or how this can be supported by adequate tools.

(Goldschmidt, Becker, Burger 2012) coin the term view-based modeling, i.e. using a domain-specific modeling language to manipulate underlying information. The abstract concept of manipulating model information by stakeholder-specific views is similar to one of the solutions presented in this paper. However this research group concentrates on text-based approaches to synchronize abstract and concrete syntax (Goldschmidt, Becker, and Uhl 2008). In (Krumeich, Werth, and Loos 2013) also contribute to view-based modeling and provide a proof-of-concept. However, both research groups do not apply their techniques to the challenges of EA documentation. Moreover, visual notations, e.g. approaches like the Graphical Modeling Framework<sup>1</sup>, are based on concrete models and thus could only be used for one concrete EA model. Since there is no common standard for an EA model (Buschle et al. 2012, Lankhorst et al. 2013), organizations commonly develop an organization specific model for their EA with respect to the organization's terminology.

## REQUIREMENTS FOR AUTOMATED EA DOCUMENTATION CONFLICT RESOLUTION

Approaches for EA documentation are proposed in several publications (Farwick et al. 2011a; Fischer et al. 2007; Moser et al. 2009). Nevertheless, current literature lacks a uniform and proper definition of the terminology in this field. We define the term EA documentation as, *a process for the acquisition and maintenance of EA data from information sources and the processing of this data for an EA model*. In this vein, information sources describe existing systems of the organization as well as roles providing this information. Building upon this definition, automated EA documentation stands for the (semi-) automated acquisition and maintenance of information from existing systems that are used by the organization, e.g. (Farwick et al. 2013), and the (semi-) automated processing of this information for an EA model.

**Table 1. Requirements for conflict resolution of information models for automated EA documentation**

<i>Process</i>		
<i>Requirement-P1.</i>	Process capabilities to execute the conflict resolution process with human tasks and integrated technical interfaces.	(Farwick et al. 2011b)
<i>Requirement-P2.</i>	A conflict resolution must define clear responsibilities and escalation mechanisms.	(Fischer et al. 2007), Own experience
<i>Collaboration</i>		
<i>Requirement-C1.</i>	The system must provide facilities to resolve conflicts collaboratively by involving Data Owners and EA Stakeholders.	(Farwick et al. 2011b), Own experience
<i>Requirement-C2.</i>	The system must be able to delegate model conflicts to another role.	(Fischer et al. 2007), Own experience
<i>Conflicts</i>		
<i>Requirement-M1.</i>	Data Owners and EA Stakeholders must be empowered to resolve conflicts.	(Farwick et al. 2011b)
<i>Requirement-M2.</i>	The system must be able to define multiple conflict resolutions at once (batch).	Own experience
<i>Usability</i>		
<i>Requirement-U1.</i>	EA Coordinators, Data Owners, and EA Stakeholders must understand mechanisms for conflict resolution.	Own experience
<i>Requirement-U2.</i>	Mechanisms for conflict resolution must be intuitive to Data Owners and EA Stakeholders.	Own experience
<i>Technology</i>		
<i>Requirement-T1.</i>	Support for identity reconciliation and consistency check of the EA repository.	(Farwick et al. 2011b), (Fischer et al. 2007)

<sup>1</sup>[http://www.eclipse.org/projects/project.php?id=modeling\\_gmf](http://www.eclipse.org/projects/project.php?id=modeling_gmf), last-accessed: Jan. 31, 2013.

Requirements for the conflict resolution for automated EA documentation (cf. Table 1) are derived based on our previous work (Buschle et al. 2012) and an investigation of relevant literature outlined above. Some of the requirements originate from our own experience and are validated by expert interviews we conducted to evaluate our approach (cf. Section Evaluation).

Process capabilities that execute the conflict resolution are necessary to support and enhance existing automated EA documentation processes (Farwick et al. 2011a). This includes the utilization of human tasks to involve Data Owners and EA Stakeholders in the resolution of conflicts and an integration of technical interfaces. Addressing the former, our approach employs interactive conflict resolution visualizations explained in the following, whereas the latter are necessary to 1) connect information sources, 2) propagate changes and 3) validate actions performed by EA Coordinator, EA Repository Manager, Data Owners, and EA Stakeholders within interactive visualizations. Conflict resolutions rely on collaboration between these roles. From recent literature we found that the system needs to provide facilities to resolve these conflicts in a collaborative setting (Farwick et al. 2011b). The escalation mechanism requires the delegation of human tasks for the conflict resolution (cf. Section Evaluation). Automated EA documentation requires manual conflict resolution in case the automated model transformation could not be entirely completed. Since these conflicts typically apply to many instances, the system needs to be able to resolve multiple conflicts at once and apply these resolutions in a batch-processing mode. Reasons for conflicts that cannot be resolved automatically might be, for instance missing data on particular entities in the information source, an undesired level of abstraction from imported data, or duplicate elements.

Usability requirements originate from “the role of group cognition in a large-scale, multi-functional, complex and long-term technical collaboration” as detailed by (Espinosa, Armour, and Boh 2011; Espinosa, Armour, Boh, and Clark 2013), are validated by our expert interviews, and deal with the fact that the conflict resolution needs to be performed with EA Stakeholders and Data Owners. These roles might not know the EA repository very well or have no technical background. Hence, the conflict resolution needs to be designed in a way that Data Owners and EA Stakeholders are able to understand and contribute.

It is necessary to reduce manual conflict resolutions in the automated EA documentation process to achieve our longer-term goal of reducing the prevailing documentation effort. This technical requirement addresses the automated reconciliation of imported elements with the EA repository as well as consistency checks. In this paper we will focus on the process, collaboration, mapping, and usability requirements that need to be fulfilled for the conflict resolution. Although this technical requirement is not directly addressed in the conflict resolution process, our approach would considerably benefit from a proper solution of this problem.

## CONFLICT RESOLUTION FOR AUTOMATED EA DOCUMENTATION

The existing processes for automated EA documentation (Farwick et al. 2011a) can be extended by means for the resolution of conflicts. Our solution consists of a detailed process description modeled with BPMN 2.0 including roles and artifacts. It employs interactive visualizations developed for this purpose based on an existing visualization framework (Schaub, Matthes, and Roth 2012; Hauder, Matthes, Roth, and Schulz 2012).

### Conflict Resolution Process

The main success scenario of the conflict resolution process (cf. Figure 1) starts with a conflict set from the automated EA documentation process. This set includes conflicts that could not be resolved automatically during model transformation and identity reconciliation steps. The EA Repository Manager supports the conflict resolution and tries to resolve these conflicts. Conflicts that can be resolved by the EA Repository Manager are forwarded either to an EA Stakeholder or the EA Coordinator depending on the release. Only major releases are forwarded to the EA Stakeholder for a final validation. This validation is performed with an automatically generated task containing the conflict resolution visualization. If unable to resolve the conflict, the EA Repository Manager instantiates a task with a conflict resolution visualization. In this step conflict-affected entities to be resolved are selected and this task is delegated to the responsible Data Owner of the information source that triggered the conflict.

The responsible Data Owner receives a new task including the conflict resolution visualization in a worklist. The Data Owner is responsible for the information source and, thus, will be able to resolve most conflicts without involving an EA Stakeholder. Resolved conflicts are either directly propagated to the EA repository or a new task is generated automatically with a validation request of the responsible EA Stakeholder. If the Data Owner is unable to resolve the conflict, the task is forwarded to an EA Stakeholder (possibly with annotations of the Data Owner).

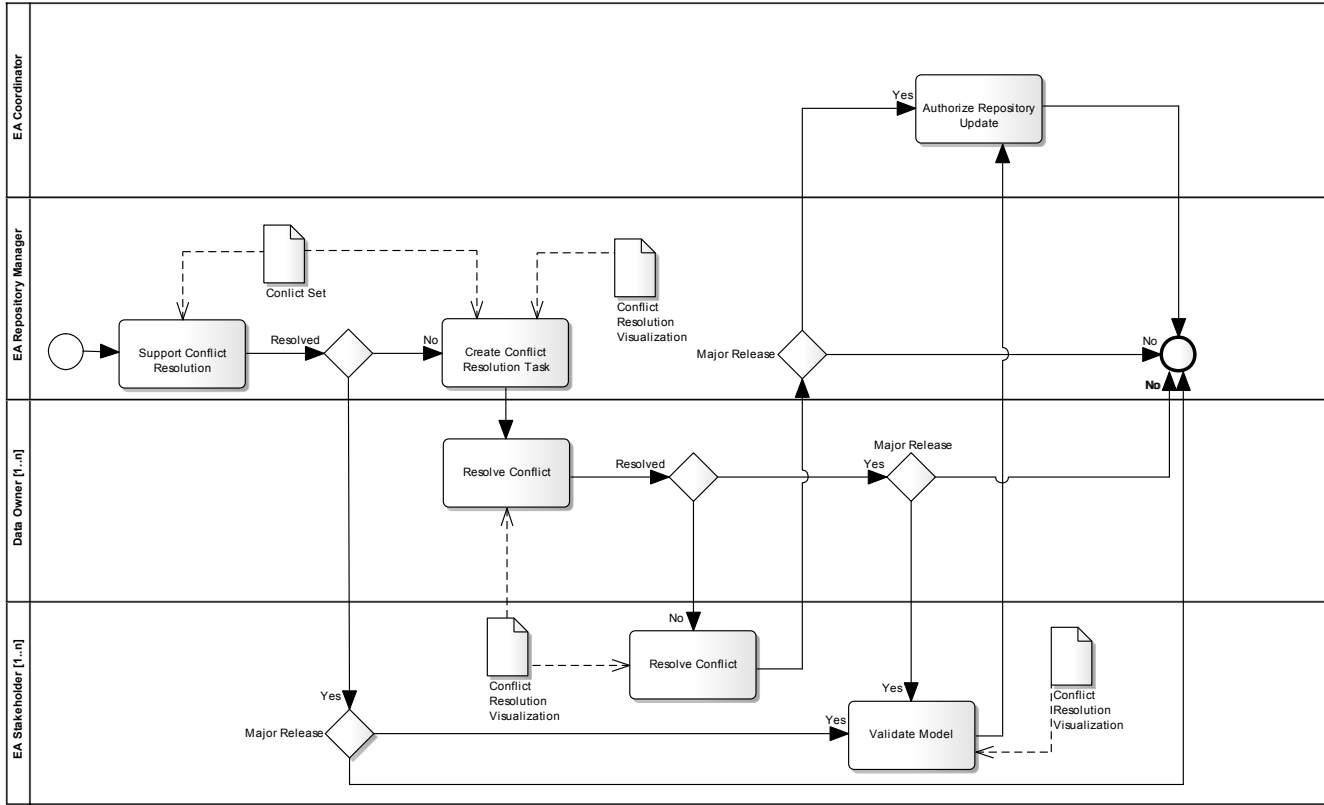


Figure 1. BPMN 2.0 process for the main success scenario of the conflict resolution for incomplete model transformations

Only if EA Repository Manager and Data Owner are unable to resolve the conflict, the respective EA Stakeholder needs to be contacted. In this case, the EA Stakeholder receives the configured conflict resolution visualization that might be annotated with comments from Data Owner or EA Repository Manager. We argue that the EA Stakeholder might not have any technical background (Kurpuweit and Winter 2007), sufficient skills, access rights, etc. to maintain the EA tool. Using conflict resolution visualizations, EA Stakeholders are empowered to resolve conflicts visually. If they are not responsible, EA stakeholders might delegate tasks to other stakeholders.

Resolved conflicts are directly propagated to the EA repository or the EA Coordinator is asked to authorize the update if a major release is performed. The proposed process respects the escalation requirement and only involves EA Stakeholders if EA Repository Manager and Data Owner were not able resolve the conflicts.

### Conflict Resolution Visualization

The aforementioned process utilizes the conflict resolution visualization to support Data Owners and EA Stakeholders during the resolution of conflicts and validation thereof. It is interactive and can be directly manipulated by the end-user. Manipulations to visualizations are directly propagated to the EA repository. Depending on the conflict to resolve in the documentation process, various types of conflict resolution visualizations are conceivable. In the following, we illustrate a conflict resolution visualization to resolve an abstraction gap based on an example given by model transformations performed by (Buschle et al. 2012).

The conflict resolution visualization is illustrated in Figure 2. The respective model conflict in this example is the missing mapping between devices and application components since this information cannot be retrieved from the ESB automatically. *Application Component* instances (see ❶) and *Device* instances (see ❷) are shown to the end-user. The entity *Infrastructure Element* instance (see ❸) holds the mapping information and is configured by the EA Repository Manager when the conflict resolution is created, in order to overcome an abstraction gap between these two entities.

After the EA Repository Manager created the configuration for the visualization, it is forwarded to the responsible Data Owner of the ESB or an EA Stakeholder if the Data Owner is unable to resolve the conflict. Any existing mappings within

the EA repository are illustrated as tuples (see ❹) of  $n$  *Application Component* instances (see ❺) and  $m$  *Device* instances (see ❻). At this point technical solutions, e.g. ontologies, to overcome the abstraction gap could be utilized to minimize the number of elements that need to be mapped by the end-users.

The illustrated viewpoint builds upon a so-called cluster map that looks familiar to EA Stakeholders (Steen, Akehurst, ter Doest, and Lankhorst, 2004). In contrast to mere analysis support, this viewpoint can be utilized to manipulate illustrated relationships. As a result we fulfill above outlined usability requirements and enable EA Stakeholders and Data Owners to understand and contribute to the conflict resolution.

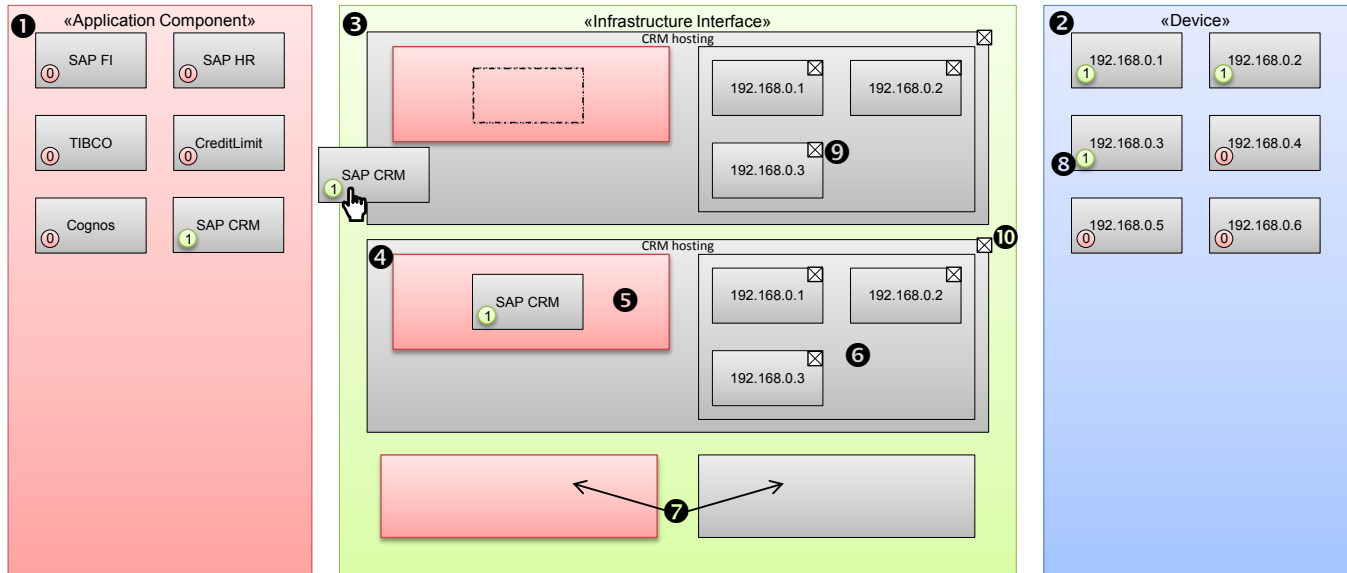


Figure 2. Interactive visualization for the conflict resolution of models for automated EA documentation

These involved roles can drag & drop elements in the interactive visualization from their type containers (see ❶ and ❷) onto the respective left and right sides of the middle column (see ❺ and ❻). Thereby, possible drop targets are highlighted according to the color of the container (cf. ❶, ❺ and ❷). Each row (see ❹) represents a relationship where end-users can add model elements to an existing relationship, e.g. indicating that a new *Device* is added to support a particular *Application Component*. Dropping an element either left or right side of the bottom element in the middle column (see ❷), a new *Infrastructure Interface* instance is created with the respective relationship.

While in most cases the name of an element is sufficient context information, an end-user may require additional information on an entity. By clicking on the entity's label, a separate window to provide this context information is opened. A counter (see ❸) indicates the number of relationships the element currently participates in.

Existing relationships already defined in the EA repository can also be manipulated. Thereby the visualization supports removing a single relation (see ❹), i.e. *Application Component* or *Device*, or the entire relationship (see ❷), an *Infrastructure Interface* instance in our example. Using this visualization various end-users are able to resolve conflicts and are supported with additional validation techniques to achieve this goal. These modifications in the conflict resolution visualization are propagated to the EA repository. Note that the presented concept abstracts from concrete types such that any model elements could be mapped, and thus, any abstraction gap within an arbitrary EA information model could be harmonized (Schaub et al. 2012; Hauder et al. 2012b).

## EVALUATION

We evaluated the above presented conflict resolution process and visualization through interviews with eight EA domain experts (cf. Table 2). We asked four respectively three questions that were directly related with the artifacts and asked for general feedback or further comments on the solution.

### Expert Interviews Regarding the Conflict Resolution Process

The experts liked the idea of delegating conflict resolution tasks to Data Owners or EA Stakeholders. One participant confirmed that the EA Repository Manager can resolve a large amount of model conflicts directly but needs help from Data Owners and EA Stakeholders when it comes to details. Another expert noted that if Data Owners take responsibility for the data they enter to the repository, they will start to understand the value of that data leading to an increased buy-in to data maintenance.

**Table 2. Participants in the evaluation of the conflict resolution process and visualization**

<i>Job title</i>	<i># years experience</i>	<i>Industry sector</i>	<i>Country</i>
Enterprise Architect	3-4	Insurance	Germany
Enterprise Architect	5	Insurance	Germany
Senior Consultant	5	Consultancy	Germany
Enterprise Architect	1-2	Finance	Germany
Enterprise Architect	6-7	Utilities	The Netherlands
N/A	8-9	Finance/Insurance	South Africa
Enterprise Architect	2	Telecommunications	United Kingdom
EA Consultant	8-9	Consultancy	Ireland

Delegation of consolidation tasks has benefits, but demands good (tool) support and maybe some extra skills at the Data Owner and EA Stakeholder roles. Regarding the use of major release in the process experts have diverse opinions. While some think it strongly depends on the context, others agreed and detailed the idea of major releases, i.e. it generally refers to major updates to functionality. From an EA perspective this functionality likely relates to enhance business capabilities which the EA needs to know and understand. For another expert it made most sense to only distribute major release information within an organization and to provide minor release updates on demand to EA Stakeholders.

An expert stated that interactive visual support enhances ownership and understanding of the EA repository amongst EA Stakeholders and Data Owners. Another expert highlighted that it is important to provide a very visual interactive aid, ideally as a gamification scenario. EA endeavors would only succeed if every EA Stakeholder not just takes partial responsibility for the EA but also is supported with proper tools and other means to make decisions. Another expert mentioned that for huge data collections and for Data Owners with technical focus ordinary lists would be sufficient.

We got diverse feedback from the experts on the final approval step of the EA Coordinator. One expert mentioned that it is a bureaucratic role and an unnecessary step in the process and it makes other roles depend on the EA Coordinator. Another expert mentioned it is very good to have a strong governance model for large enterprises; however, smaller enterprises may not need the overhead of the EA Coordinator. One expert finds these mechanisms reasonable if organizations can afford or justify the role of the EA coordinator, as this will ensure a final validation of results prior to being made available; it reduces the risk of ‘bad’ updates to the repository on which decisions will then be based upon.

### Expert Interviews Regarding the Conflict Resolution Visualization

Interviewed experts agreed interactive visualizations are useful to resolve conflicts, especially for non-technical EA Stakeholders. One expert annotated that people nowadays do not have time for a deep-dive analysis and thus any kind of tool support that facilitates decision making without a decrease in decision reliability will be helpful and appreciated.

Regarding the question if the suggested interactive visualization improves conflict resolution (e.g. save time, costs, etc.), one expert strongly agreed with the given example in the paper. However, the expert also noted that this would probably be not simple if one has virtualized environments, where mapping devices is no longer sufficient to model a ‘tight’ relation. Another expert compared interactive visualizations to Apps on smart phones, which “we only use because they look good and feel good to use”. This expert further mentioned that if people like what they use, they would use more of it. Features like autosuggestions should also be provided, making it intelligent enough to choose between system data or manual entries.

Most experts agreed that it makes sense to manipulate more than one element within a single visualization and implicitly create, update, and delete data in an EA repository via drag & drop operations. This could be facilitated with an instant validation of model constraints in the visualization, e.g. during drag & drop for relationships, type consistency. In contrast the experts did not see any meaning in showing the number (count) of referenced model elements in the visualization. Only one expert asked whether it would be possible to include comments and annotations in the visualization because this is current

practice in their organization. One expert even encouraged us to “provide as much relevant information on the screen at the same time”, making it easy to change multiple items, and provide support for touch screens.

## CONCLUSION AND OUTLOOK

In this paper we presented a solution for the conflict resolution in EA models to enable our long-term goal of automated EA documentation. The solution consists of a conflict resolution process and an interactive visualization that can be used by various end-users to resolve model conflicts. We evaluated our approach based on a prototype and interviews with EA domain experts. The proposed solution can improve existing EA documentation efforts in organizations and is one building block towards automated EA documentation. Our approach can be combined with other solutions that technically raise the level of abstraction and provide recommendations for mapping tasks to assist end-users. In line with (DeLone and McLean 2002) further research could also evaluate the organizational impact of our solution and develop different stakeholder-specific visualizations for the conflict resolution process to support other model conflicts.

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## APPENDIX

We provide additional screenshots of our system to illustrate our solution design.

